

# Tyler Gorda

POSTDOCTORAL RESEARCHER · INSTITUTE FOR THEORETICAL PHYSICS · GOETHE UNIVERSITÄT FRANKFURT AM MAIN

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## Research Interests

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**Dense nuclear matter** Bulk and transport properties of dense quark matter

**Neutron stars** Equation of state of neutron-star matter, physics of neutron-star mergers

**In-medium field theory** Equation of state of dense/hot Quantum Chromodynamic matter, transport and energy loss in a dense/hot medium

## Education

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### Doctor of Philosophy in Physics

Boulder, Colorado, USA

UNIVERSITY OF COLORADO BOULDER

Aug. 2011–Dec. 2016

- Supervisor: Prof. Paul Romatschke
- Thesis: “From pQCD to neutron stars: matching equations of state to constrain global star properties” (arXiv:1608.04358)

### Master of Science in Physics

Boulder, Colorado, USA

UNIVERSITY OF COLORADO BOULDER

Aug. 2011– Dec. 2014

- 4.000 GPA

### Bachelor of Science in Physics

New Brunswick, New Jersey, USA

RUTGERS, THE STATE UNIVERSITY OF NEW JERSEY

Aug. 2007–May 2011

- Summa cum laude, 3.976 GPA
- Double major in Physics and Mathematics

## Work Experience

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### Postdoctoral Researcher

Frankfurt, Germany

GOETHE UNIVERSITY FRANKFURT, INSTITUTE FOR THEORETICAL PHYSICS

Nov. 2023 - PRESENT

- Topics: QCD at high density, Physics of neutron-star mergers, Astrophysics of high-density QCD, Thermal field theory

### Postdoctoral Researcher

Darmstadt, Germany

TU DARMSTADT, INSTITUTE FOR NUCLEAR PHYSICS

Sept. 2020 - Sept. 2023

- Topics: QCD at high density, Astrophysics of high-density QCD, Thermal field theory

### Postdoctoral Researcher

Charlottesville, VA, USA

UNIVERSITY OF VIRGINIA

Aug. 2018 - Sept. 2020

- Topics: Thermal field theory, QCD at high density, Astrophysics of high-density QCD, Particle Propagation in a QCD medium

### Postdoctoral Researcher

Helsinki, Finland

UNIVERSITY OF HELSINKI

Aug. 2016 - Aug. 2018

- Topics: Thermal field theory, QCD at high density, Astrophysics of high-density QCD, Particle cosmology

### Research assistant

Boulder, Colorado, USA

UNIVERSITY OF COLORADO BOULDER

Oct. 2012–May 2016

- Topics: Thermal field theory, QCD at high density, Astrophysics of high-density QCD, AdS-CFT correspondence, collective flow in heavy-ion collisions

## Mentoring & Supervision

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**Sofia Blomqvist** MSc and PhD student. Official co-advisor

UNIVERSITY OF HELSINKI

*Helsinki, Finland*

*June 2023 - PRESENT*

**Andreas Geißel** PhD student. Advising and mentoring

TU DARMSTADT

*Darmstadt, Germany*

*April 2023 - PRESENT*

**Oleg Komoltsev** PhD student. Advising and mentoring

UNIVERSITY OF STAVANGER

*Stavanger, Norway*

*Jan. 2022 - PRESENT*

**Saga Säppi** MSc and PhD student. Advised and mentored

UNIVERSITY OF HELSINKI

*Helsinki, Finland*

*Aug. 2016 - July. 2018*

**Eemeli Annala** MSc and PhD student. Advised and mentored

UNIVERSITY OF HELSINKI

*Helsinki, Finland*

*Aug. 2016 - July. 2018*

## Teaching Experience

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### Lecturer (upcoming)

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

- Thermal Field Theory

*Frankfurt, Germany*

*April-July 2025*

### Teaching Assistant

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

- General Relativity

*Frankfurt, Germany*

*Oct. 2024-Feb. 2025*

### Lectures on perturbative QCD at high temperatures and density

QCD MASTER CLASS 2023

- **10 hours of lectures** to advanced PhD students, postdocs, and permanent researchers on the formalism of perturbative QCD in medium
- Topics covered: (i) framework of relativistic thermal and high-density perturbation theory, (ii) infrared problems in thermal field theory and their resolution for the pressure, (iii) the general structure of the perturbative QCD pressure, and (iv) current status of theoretical calculations.

*Saint-Jacut-de-la-Mer, France*

*June 2023*

### Lectures on Neutron Stars and the Equation of State of Dense Matter

DOKTORATSKOLLEG PARTICLES AND INTERACTIONS PH.D. RETREAT

- **3 hours of lectures**, as part of a three-day retreat for doctoral students
- Topics covered: (i) General properties of neutron stars and their observation (ii) theoretical techniques for computing the thermodynamic properties of dense matter (iii) current status of astrophysical and theoretical constraints on the behavior of dense matter.

*Graz, Austria*

*May 2022*

### Lectures on Perturbative QCD at high densities

INSTITUTO GALEGO DE FISICA DE ALTAS ENERGIAS, UNIVERSITY OF SANTIAGO DE COMPOSTELA (ONLINE)

- **2 hours of lectures**, as part of course on Neutron-Star physics
- Topics covered: (i) framework of relativistic thermal and high-density perturbation theory, (ii) infrared problems in thermal field theory and their resolution for the pressure, (iii) the general structure of the perturbative QCD pressure, and (iv) current status of theoretical calculations.

*Santiago de Compostela, Spain*

*Nov. 2021*

### Teaching Assistant

UNIVERSITY OF COLORADO BOULDER

- Undergraduate introductory mechanics for majors
- Undergraduate introductory electromagnetism for majors
- Undergraduate introductory mechanics for non-majors
- Undergraduate introductory electromagnetism for non-majors

*Boulder, Colorado, USA*

*2011, 2014-2016*

## Presentations & Talks

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In total: 2 colloquia, 15 plenary talks, 24 invited talks, 15 seminars, 8 contributed talks.

Recent or notable talks include:

<b>The 3rd APCTP-Triumf Joint Workshop: From Nuclei to Neutron Stars</b>	<i>Busan, South Korea</i>
INVITED PLENARY TALK “Constraining strongly interacting matter at the highest densities with perturbative QCD”	<i>September 2024</i>
<b>New aspects of nuclear physics and nuclear astrophysics</b>	<i>Seoul, South Korea</i>
INVITED PLENARY TALK “Quark matter in the cores of massive neutron stars”	<i>September 2024</i>
<b>INT-24-89W: EOS Measurements with Next-Generation Gravitational-Wave Detectors</b>	<i>Seattle, Washington</i>
PLENARY TALK “Listening to the long ringdown”	<i>September 2024</i>
<b>Strong and Electro-weak Matter 2024</b>	<i>Frankfurt, Germany</i>
PLENARY TALK “Pressure and speed of sound in (two-flavor) color-superconducting quark matter at NLO”	<i>August 2024</i>
<b>CRC-TR 211 (Strong-interaction matter under extreme conditions) Meeting</b>	<i>Frankfurt, Germany</i>
INVITED PLENARY TALK “Listening to the long ringdown”	<i>July 2024</i>
<b>Heidelberg University</b>	<i>Heidelberg, Germany</i>
INVITED THEORY COLLOQUIUM “Constraining the behavior of strongly interacting matter at the highest densities”	<i>June 2024</i>
<b>ELEMENTS Annual Conference 2024</b>	<i>Frankfurt, Germany</i>
INVITED COLLOQUIUM “Constraining the behavior of strongly interacting matter at the highest densities”	<i>April 2024</i>
<b>Institute for Nuclear Theory</b>	<i>Seattle, Washington</i>
INVITED S@INT SEMINAR “Probing the behavior of strongly interacting matter at the highest densities”	<i>April 2024</i>
<b>University of Michigan</b>	<i>Ann Arbor, Michigan</i>
SEMINAR “Constraining the microphysics of high-density QCD”	<i>March 2024</i>
<b>Quark Matter 2023</b>	<i>Houston, Texas, USA</i>
INVITED PLENARY TALK, “Quark Matter and Nuclear Astrophysics”	<i>September 2023</i>
<b>Rencontres de Moriond: Gravitation</b>	<i>La Thuile, Italy</i>
INVITED PLENARY TALK, “What multimessenger observations have told us about the EoS of NS matter”	<i>Mar. 2023</i>
<b>Strong and Electro-weak Matter 2022</b>	<i>Saclay, France</i>
INVITED PLENARY TALK, “Bayesian constraints on the neutron-star equation of state with QCD input”	<i>June 2022</i>
<b>APS April Meeting (Session Q04: Mergers of Neutron Stars: Nuclear Physics from Gravitational Waves)</b>	<i>New York City, New York USA</i>
INVITED TALK, “High-Density Quark Matter in the Cores of Neutron Stars”	<i>Apr. 2022</i>

## Service

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<b>Astrocoffee Seminar Series Organizer</b>	<i>Jan. 2024-PRESENT</i>
SEMINAR SERIES AT GOETHE UNIVERSITY ON RECENT DEVELOPMENTS IN ASTROPHYSICS, COSMOLOGY, AND ADJACENT TOPICS	
<b>Member of the IReNA Online Seminar Organizing Committee</b>	
INTERNATIONAL RESEARCH NETWORK FOR NUCLEAR ASTROPHYSICS	<i>Sept. 2021-May 2022</i>

## Refereed Publications

VARIOUS JOURNALS

2018-PRESENT

- Physical Review Letters
- Physical Review D
- Physics Letters B
- Monthly Notices of the Royal Astronomical Society Letters
- Journal of High Energy Physics (JHEP)
- International Journal of Modern Physics A
- Universe
- European Physical Journal C

## Founding member of the Graduate Liaison Committee

University of Colorado Boulder, USA

FOUNDED TO BETTER SUPPORT GRADUATE STUDENTS IN THEIR COMMUNICATION WITH THE PHYSICS DEPARTMENT

2014-2016

## Coordinated Programs and Professional Societies

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### Member of the Collaborative Research Center TransRegio 211 (Strong-interaction matter under extreme conditions)

April 2022-PRESENT

COORDINATED PROGRAM BETWEEN BIELEFELD UNIVERSITY, TU DARMSTADT, AND GOETHE UNIVERSITY, TO DECISIVELY ADVANCE OUR UNDERSTANDING OF STRONG-INTERACTION MATTER UNDER EXTREME CONDITIONS OF TEMPERATURE AND DENSITY

### Member of ELEMENTS: Exploring the Universe from Microscopic to Macroscopic Scales

April 2022-PRESENT

CLUSTER PROJECT BETWEEN GOETHE UNIVERSITY, TU DARMSTADT, JLU GIESSEN, AND GSI/FAIR TO ADDRESS THE QUESTION OF THE ORIGIN OF THE HEAVY CHEMICAL ELEMENTS, SUCH AS PLATINUM AND GOLD, IN OUR UNIVERSE.

### Member of the American Physical Society

Feb. 2022-PRESENT

## Outreach & Media Coverage

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### Helsingin Sanomat (largest newspaper in Finland), Phys.org, Universe Today, Space Daily articles about my work Phys. Rev. Lett. 133.7 (2024), 071901

Aug. 2024

### Phys.org (2 articles), Yahoo News, Space.com, Universe Today, Sci.News articles about my work Nat Commun. 2023

Dec./Jan. 2023

### PNAS article mentioning my work Nature Phys. 2020

Nov. 2020

### Podcast Interview with The Cosmic Companion

June 2020

DISCUSSING EVIDENCE FOR QUARK-MATTER CORES IN MASSIVE NEUTRON STARS IN Nature Phys. 2020

### Phys.org, Physicsworld, Medium, and IFLS articles

June 2020

MORE ARTICLES ABOUT MY WORK Nature Phys. 2020

### Phys.org article about my work on the Two-Higgs-Doublet Model Phys. Rev. Lett. 121 191802 (2018)

Nov. 2018

### Sky and Telescope article mentioning my work constraining the neutron-star-matter equation of state using gravitational waves Phys. Rev. Lett. 120 172702 (2018)

May 2018

### APS Synopsis article on the same work Phys. Rev. Lett. 120 172702 (2018)

Apr. 2018

## Software/Programming Experience

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**Programming** Extensive experience with Mathematica and Python, and good working knowledge of C/C++

**General IT**  $\LaTeX$ (typesetting), GNU/Linux (operating system), Git (version control)

## Languages

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- English** Mother tongue  
**German** Level A2.2  
**French** Approximate Level B1

## Publications

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Summary of papers on [Inspire-HEP](#). As of 01 November 2024: 2,452, citations, h-index 19

Note that **alphabetical ordering** of authors is the community standard in theoretical high-energy physics

### Peer-Reviewed Articles

- [31] A. Geißel, **T. Gorda**, and J. Braun. “Pressure and speed of sound in two-flavor color-superconducting quark matter at next-to-leading order”. *Phys. Rev. D* 110.1 (2024), 014034. arXiv: 2403.18010 [hep-ph].
- [30] C. Ecker, **T. Gorda**, A. Kurkela, and L. Rezzolla. “Listening to the long ringdown: a novel way to pinpoint the equation of state in neutron-star cores” (Mar. 2024). arXiv: 2403.03246 [astro-ph.HE]. (Accepted to Nature Communications).
- [29] J. Cruz Rojas, **T. Gorda**, C. Hoyos, N. Jokela, M. Järvinen, A. Kurkela, R. Paatelainen, S. Säppi, and A. Vuorinen. “Estimate for the Bulk Viscosity of Strongly Coupled Quark Matter Using Perturbative QCD and Holography”. *Phys. Rev. Lett.* 133.7 (2024), 071901. arXiv: 2402.00621 [hep-ph].
- [28] O. Komoltsev, R. Somasundaram, **T. Gorda**, A. Kurkela, J. Margueron, and I. Tews. “Equation of state at neutron-star densities and beyond from perturbative QCD”. *Phys. Rev. D* 109.9 (2024), 094030. arXiv: 2312.14127 [nucl-th].
- [27] G. D. Moore and **T. Gorda**. “Bounding the QCD Equation of State with the Lattice”. *JHEP* 12 (2023), 133. arXiv: 2309.15149 [nucl-th].
- [26] **T. Gorda**, R. Paatelainen, S. Säppi, and K. Seppänen. “Equation of State of Cold Quark Matter to  $O(\alpha_s^3 \ln \alpha_s)$ ”. *Phys. Rev. Lett.* 131.18 (2023), 181902. arXiv: 2307.08734 [hep-ph].
- [25] **T. Gorda**, R. Paatelainen, S. Säppi, and K. Seppänen. “Soft gluon self-energy at finite temperature and density: hard NLO corrections in general covariant gauge”. *JHEP* 08 (2023), 021. arXiv: 2304.09187 [hep-ph].
- [24] E. Annala, **T. Gorda**, J. Hirvonen, O. Komoltsev, A. Kurkela, J. Nättilä, and A. Vuorinen. “Strongly interacting matter exhibits deconfined behavior in massive neutron stars”. *Nat Commun.* 14 (2023), 8451. arXiv: 2303.11356 [astro-ph.HE].
- [23] **T. Gorda**, O. Komoltsev, A. Kurkela, and A. Mazeliauskas. “Bayesian uncertainty quantification of perturbative QCD input to the neutron-star equation of state”. *JHEP* 06 (2023), 002. arXiv: 2303.02175 [hep-ph].
- [22] **T. Gorda**, K. Hebeler, A. Kurkela, A. Schwenk, and A. Vuorinen. “Constraints on Strong Phase Transitions in Neutron Stars”. *Astrophys. J.* 955.2 (2023), 100. arXiv: 2212.10576 [astro-ph.HE].
- [21] P. Arnold, **T. Gorda**, and S. Iqbal. “The LPM effect in sequential bremsstrahlung: incorporation of “instantaneous” interactions for QCD”. *JHEP* 11 (2022), 130. arXiv: 2209.03971 [hep-ph].

- [20] **T. Gorda**, J. Österman, and S. Säppi. “Augmenting the residue theorem with boundary terms in finite-density calculations”. *Phys. Rev. D* 106.10 (2022), 105026. arXiv: 2208.14479 [hep-th]. **(Editor’s suggestion)**.
- [19] H. Schatz et al. “Horizons: nuclear astrophysics in the 2020s and beyond”. *J. Phys. G* 49.11 (2022), 110502. arXiv: 2205.07996 [nucl-ex].
- [18] **T. Gorda**, O. Komoltsev, and A. Kurkela. “Ab-initio QCD calculations impact the inference of the neutron-star-matter equation of state”. *Astrophys. J.* 950.2 (June 2023), 107. arXiv: 2204.11877 [nucl-th].
- [17] **T. Gorda**, A. Kurkela, J. Österman, R. Paatelainen, S. Säppi, P. Schicho, K. Seppänen, and A. Vuorinen. “Degenerate fermionic matter at N3LO: Quantum electrodynamics”. *Phys. Rev. D* 107.3 (2023), L031501. arXiv: 2204.11893 [hep-ph].
- [16] **T. Gorda**, A. Kurkela, J. Österman, R. Paatelainen, S. Säppi, P. Schicho, K. Seppänen, and A. Vuorinen. “Soft photon propagation in a hot and dense medium to next-to-leading order”. *Phys. Rev. D* 107.3 (2023), 036012. arXiv: 2204.11279 [hep-ph].
- [15] **T. Gorda** and S. Säppi. “Cool quark matter with perturbative quark masses”. *Phys. Rev. D* 105.11 (2022), 114005. arXiv: 2112.11472 [hep-ph].
- [14] P. Arnold, **T. Gorda**, and S. Iqbal. “The LPM effect in sequential bremsstrahlung: analytic results for sub-leading (single) logarithms”. *JHEP* 04 (2022), 085. arXiv: 2112.05161 [hep-ph].
- [13] E. Annala, **T. Gorda**, E. Katerini, A. Kurkela, J. Nätttilä, V. Paschalidis, and A. Vuorinen. “Multimessenger Constraints for Ultradense Matter”. *Phys. Rev. X* 12.1 (2022), 011058. arXiv: 2105.05132 [astro-ph.HE].
- [12] **T. Gorda**, A. Kurkela, R. Paatelainen, S. Säppi, and A. Vuorinen. “Soft Interactions in Cold Quark Matter”. *Phys. Rev. Lett.* 127.16 (2021), 162003. arXiv: 2103.05658 [hep-ph].
- [11] **T. Gorda**, A. Kurkela, R. Paatelainen, S. Säppi, and A. Vuorinen. “Cold quark matter at N3LO: Soft contributions”. *Phys. Rev. D* 104.7 (2021), 074015. arXiv: 2103.07427 [hep-ph]. **(Editor’s suggestion)**.
- [10] P. Arnold, **T. Gorda**, and S. Iqbal. “The LPM effect in sequential bremsstrahlung: nearly complete results for QCD”. *JHEP* 11 (2020), 053. arXiv: 2007.15018 [hep-ph].
- [9] E. Annala, **T. Gorda**, A. Kurkela, J. Nätttilä, and A. Vuorinen. “Evidence for quark-matter cores in massive neutron stars”. *Nature Phys.* 16.9 (2020), 907–910. arXiv: 1903.09121 [astro-ph.HE].
- [8] **T. Gorda**, A. Helset, L. Niemi, T. V. I. Tenkanen, and D. J. Weir. “Three-dimensional effective theories for the two Higgs doublet model at high temperature”. *JHEP* 02 (2019), 081. arXiv: 1802.05056 [hep-ph].
- [7] **T. Gorda**, A. Kurkela, P. Romatschke, S. Säppi, and A. Vuorinen. “Next-to-Next-to-Next-to-Leading Order Pressure of Cold Quark Matter: Leading Logarithm”. *Phys. Rev. Lett.* 121.20 (2018), 202701. arXiv: 1807.04120 [hep-ph].
- [6] J. O. Andersen, **T. Gorda**, A. Helset, L. Niemi, T. V. I. Tenkanen, A. Tranberg, A. Vuorinen, and D. J. Weir. “Nonperturbative Analysis of the Electroweak Phase Transition in the Two Higgs Doublet Model”. *Phys. Rev. Lett.* 121.19 (2018), 191802. arXiv: 1711.09849 [hep-ph].
- [5] E. Annala, **T. Gorda**, A. Kurkela, and A. Vuorinen. “Gravitational-wave constraints on the neutron-star-matter Equation of State”. *Phys. Rev. Lett.* 120.17 (2018), 172703. arXiv: 1711.02644 [astro-ph.HE]. **(Featured in Physics, Editor’s suggestion)**.

- [4] I. Ghisoiu, **T. Gorda**, A. Kurkela, P. Romatschke, S. Säppi, and A. Vuorinen. “On high-order perturbative calculations at finite density”. *Nucl. Phys.* B915 (2017), 102–118. arXiv: 1609.04339 [hep-ph].
- [3] **T. Gorda**. “Global properties of rotating neutron stars with QCD equations of state”. *Astrophys. J.* 832.1 (2016), 28. arXiv: 1605.08067 [astro-ph.HE].
- [2] **T. Gorda** and P. Romatschke. “Equation of state in two-, three-, and four-color QCD at nonzero temperature and density”. *Phys. Rev.* D92.1 (2015), 014019. arXiv: 1412.6712 [hep-ph].
- [1] **T. Gorda** and P. Romatschke. “Precision studies of  $v_n$  fluctuations”. *Phys. Rev.* C90.5 (2014), 054908. arXiv: 1406.6405 [nucl-th].

## Preprints

- [1] A. Rajan, **T. Gorda**, S. Liuti, and K. Yagi. “Bounds on the Equation of State of Neutron Stars from High Energy Deeply Virtual Exclusive Experiments” (2018). arXiv: 1812.01479 [hep-ph].

## Proceedings

- [6] **T. Gorda**. “Quark matter and nuclear astrophysics: recent developments”. Dec. 2023. arXiv: 2312.09967 [nucl-th].
- [5] S. Bogdanov et al. “Snowmass 2021 Cosmic Frontier White Paper: The Dense Matter Equation of State and QCD Phase Transitions”. *2022 Snowmass Summer Study*. Sept. 2022. arXiv: 2209.07412 [astro-ph.HE].
- [4] **T. Gorda**. “Improving the cold quark-matter pressure via soft interactions at N3LO”. *EPJ Web Conf.* 258 (2022), 05004. arXiv: 2111.11944.
- [3] P. Arnold, **T. Gorda**, and S. Iqbal. “The problem of overlapping formation times: A (nearly) complete result for QCD”. Vol. *HardProbes2020*. 2021, 181.
- [2] P. Arnold, **T. Gorda**, and S. Iqbal. “The Problem of overlapping formation times: In-medium virtual corrections for QCD”. Ed. by F. Liu, E. Wang, X.-N. Wang, N. Xu, and B.-W. Zhang. Vol. 1005. 2021, 121909.
- [1] E. Annala, **T. Gorda**, A. Kurkela, J. Nättilä, and A. Vuorinen. “Constraining the properties of neutron-star matter with observations”. *Proceedings: INTEGRAL 2019*. 2019. arXiv: 1904.01354 [astro-ph.HE].

## Thesis

- [1] **T. Gorda**. “From pQCD to neutron stars: matching equations of state to constrain global star properties”. PhD thesis. Colorado U., 2016. arXiv: 1608.04358 [nucl-th].